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Bellcomm

QUARTERLY PROGRESS REPORT

October November December

1969

I. M. Ross
President

Bellcomm
955 L'Enfant Plaza North, S. W. Washington, D. C. 20024

Report No. 70-101-1
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QUARTERLY PROGRESS REPORT

ABSTRACT

The activities of Bellcomm during the quarter ending December 31, 1969 are summarized. Reference is made to reports and memoranda issued during this period covering particular technical studies.

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APOLLO/SATURN SYSTEMS ENGINEERING
MISSION PLANNING

Mission Assignments

A revised issue of the Apollo Flight Mission Assignments document was approved in October and subsequently published by NASA. This issue established the Principal and Secondary Detailed Objectives for the H-1 mission as well as the photography of candidate exploration sites as a Primary Objective for the H-series missions. The ΔV requirements for the H-missions were included. Also, appendixes for the J-series of missions were added to identify for each mission a set of preliminary Primary Objectives and the tentative landing sites. Photography requirements for all missions were expanded to include the lenses and film in addition to the cameras assigned to each flight. The mission assignments of the lunar orbital science experiments approved by the MSFEB were identified in this issue.

A new issue of the Apollo Flight Mission Assignments document was prepared in draft form. Coordination with the Centers is anticipated in the next quarter. The draft identifies the science rationale, the Primary Objectives and the landing sites for the remaining Apollo missions.

To assist the Apollo Site Selection Board, Bellcomm chaired a site selection leadtime task force which was organized to study the factors controlling site selection leadtime and to determine those actions which could be taken to reduce the required leadtime. Significant leadtime items were identified and the sensitivity of mission planning to these items is being examined.

Technical activities related to Apollo 12 included a review of changes to the Primary and Detailed Objectives, and reviews of the Final Launch and Flight Mission Rules, the Mission Operations Report and the Apollo Press Kit.

Vehicle Performance

Monthly preparation and delivery of Weight and Performance Reports, as well as presentation of weight and performance status at Apollo Program Office Reviews, continued.

Changes to spacecraft control weights and performance parameters for the H missions were coordinated with MSC and subsequently incorporated in a revision to the Apollo Program Specification. Work continued on establishing new control weights for the J missions. The dependence of these weights on the specific launch dates and landing sites is being considered.

Analysis and coordination with the Centers to establish the launch vehicle payload requirements for the J missions continued. MSFC has verified a baseline capability of 105,000 lbs for SA-512 and SA-513, and 105,500 lbs for SA-511, SA-514 and SA-515. Some capability beyond this baseline will be defined for each vehicle when the specific launch dates and landing sites are firmly established. In addition, payload capability up to 107,000 lbs (if required) can be obtained by exercising mission options such as reducing the earth parking orbit altitude and reducing the launch window duration.

Mission Analysis

Hybrid mission lunar surface accessibility was under study with emphasis on the J missions. Because of the increased spacecraft weight for these missions, accessibility is very sensitive to launch month, lighting requirements, and operational constraints such as orbital and surface staytimes.

The computations of hybrid trajectory profiles for both H and J missions in the scheduled primary and backup months were completed. These data are required for the generation of ΔV requirements which are to be included in future issues of the Apollo Flight Mission Assignments document. In addition, the data are required for the determination of launch vehicle mission-specific energy requirements which enable the launch vehicle injected payload capability to be established for each mission.

Trajectory data for missions to the Marius Hills landing site during the period from July through November 1971 were generated. Analysis of these data revealed the feasibility of a mission to Marius Hills in any month from July through October.(1) The scheduled orbital science activity during missions in September and October could be completed only if the SPS propellants budgeted for LM rescue remained available after rendezvous. The ΔV requirements for November precluded a mission to Marius Hills during that month.

A study of the feasibility of a mission to Tycho in February or March 1973 was begun. Preliminary results show that a hybrid trajectory maintaining Descent Propulsion System abort capability is possible if a three-impulse lunar orbit insertion maneuver is employed. This technique requires only one additional

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(1) Feasibility of a Marius Hills Mission in the Period From July Through October 1971, Memorandum for File, D. R. Anselmo, December 24, 1969.

SPS firing, but extends the time from the first firing to the third firing to approximately 35 hours. An intermediate lunar orbit having an apolune radius of 12,000 nm results.

A criterion was developed for predicting the relative azimuth angle between the sun and the flight path for landings at high-latitude sites.(2) This study showed that landing visibility would be improved for high latitude landings where the flight path angle is approximately equal to the sun's elevation (normal wash-out region). Another study of visibility conditions showed that, from the point of view of visibility alone, sites with latitudes greater than 20° can be targeted for the first day (lunar dawn) and any subsequent day until glare becomes a problem.(3) Sites with latitudes less than 20° can be targeted for the first day (lunar dawn), for the second day (depending on the latitude), and then for the fifth and subsequent days until glare becomes a problem. Since these conclusions offer the possibility of opening up the lighting band and the launch windows, it was concluded that the impact of other factors, such as thermal design and mission ΔV requirements, should be examined.

The effects of the LM Landing Point Designator (LPD) errors in making redesignations to a given target were determined. It was found that LPD error effects can be substantially reduced through the use of redesignation procedures which involve either redesignation at a specific altitude optimized for each predicted landing site or through the use of multiple redesignations.(4) It was further shown that the ΔV required to land in a given target area can be significantly reduced if uprange and right redesignation capability is allowed along with downrange and left redesignation capability.(5) A study was also made of the site-dependent redesignation plus manual maneuvering ΔV requirements for nine

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(2) Improved Lunar Landing Visibility Resulting from Greater Expected Relative Sun Azimuth for High Latitude Sites, Memorandum for File, R. A. Bass, October 15, 1969.

(3) Can High Latitude Sites be Their Own Recycle Sites?, Memorandum for File, D. B. James, December 3, 1969.

(4) Effects of Landing Point Designator Errors on Landing the Lunar Module in a Circular Target Area, Memorandum for File, K. P. Klaasen, December 2, 1969.

(5) Effects of Including Uprange and Right Redesignation Capability on Landing the Lunar Module in a Circular Target Area, Memorandum for File, K. P. Klaasen, December 22, 1969.

candidate lunar landing sites. These ΔV requirements were then used to estimate the LM landed payload capability to each site.[6]

An investigation of a LM descent redesignation strategy for avoiding craters was made using a relationship between the LM descent redesignation ΔV budget and a measure of the roughness of a landing site.[7] The LM descent redesignation model stipulated that when the LPD indicated the landing point was within a crater, redesignation was made to a nearby improved region. To allow for LPD errors, the time for redesignation was delayed until the crater diameter equaled that of the LPD error circle. The results of the probability analysis gave the expected number of redesignations and the corresponding ΔV required by the LM as functions of site roughness.

The effect of using a lower CSM lunar parking orbit altitude for rescue of the LM following an abort during descent was studied.[8] Two possible rendezvous sequences were considered: a 6-burn sequence for cases of LM abort from descent orbit initiation (DOI) to powered descent initiation (PDI) and a 5-burn sequence for aborts from PDI to touchdown. The SPS ΔV required for rescue of the LM varies between 225 and 136 fps for CSM parking orbit altitudes between 60 and 26.8 nm. It was concluded that the use of a lower parking orbit results in acceptable abort situations.

A study was completed which formalized the description of interrelationships between significant lunar trajectory parameters and their influence on translunar and transearth trajectories.[9] The geometric characteristics of such trajectories and their dependence on the various parameters were illustrated.

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(6) Site Dependent Redesignation and Manual Maneuvering Delta-V Requirements, Memorandum for File, K. P. Klaasen, December 31, 1969.

(7) Relating the LM Descent Redesignation ΔV Budget to the Landing Ellipse Evaluation Number "N", TM-69-2015-6, P. Gunther, V. Hamza, A. W. Zachar, November 18, 1969.

(8) Effect of Lower CSM Parking Orbit on Rescue After Abort During LM Descent, Memorandum for File, D. G. Estberg, December 18, 1969.

(9) Lunar Trajectory Geometry, TM-69-2011-3, K. M. Carlson, December 23, 1969.

A patched conic trajectory analysis study utilizing non-free return trajectories was completed for lunar exploration missions involving three-day surface staytimes for the 1971, 1972 and 1973 period.[10]

Conic trajectory calculations are much more economical in computer time than are precision integrated trajectories, and when calibrated they provide acceptable accuracy for preliminary mission planning studies. Velocity corrections have now been determined specifically for hybrid lunar trajectories. Lunar orbit insertion corrections range from 40 to 50 fps and transearth injection corrections are nearly constant at 50 fps.

Tracking coverage provided by the 210-foot antennas which have been available for previous Apollo lunar missions was determined for the Apollo 13 mission.[11] The coverage provided by the antenna at Parkes, Australia, for Apollo 13 is almost negligible and does not result in any useful addition to the Goldstone coverage.

Guidance and Navigation

Work on lunar orbit navigation continued. A method of orbit determination involving the use of time-varying orbital elements was tested with Apollo 11 data and found very good.[12]

The L-1 gravity field and orbit prediction procedures used for Apollo 12 were evaluated. These topics were discussed at Apollo Program Office reviews and with the Mission Director.

Work was begun on orbit determination for the Apollo 12 S-IVB stage which is in a long period earth orbit. Orbit predictions which are based upon translunar trajectory data are being used to obtain photographic records for this study.

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(10) Mission Analysis for Lunar Exploration Landing Sites, TM-69-2011-4, T. L. Yang, October 29, 1969.

(11) 210 Foot Antenna Coverage for the Apollo 13 Mission, Memorandum for File, D. R. Anselmo, M. K. Burchette, December 3, 1969.

(12) Orbit Determination and Prediction for Apollo 11 LPO Using POLAR, TM-69-2014-10, M. V. Bullock, A. J. Ferrari, December 19, 1969.

The final meeting of the Apollo Software Task Force was coordinated and documented.[13] This group was formed in 1967 and met 16 times as it reviewed the procedures being used to develop the Apollo flight software.

A study was made of the extent of knowledge of lunar surface roughness near Censorinus.[14] The manner in which uncertainties in Lunar Orbiter photography translate into slope uncertainties over base lengths of seven meters was used to show that slope uncertainty at possible landing points is so large that the likelihood of LM tip-over is difficult to determine rigorously.

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(13) Minutes of Software Task Force Meeting #16, Memorandum for File, W. G. Heffron, October 27, 1969.

(14) Uncertainties in Photographic Determination of Expectable LM Tilt Near the Crater Censorinus, Memorandum for File, D. D. Lloyd, December 1, 1969.

Apollo Program Specification

Changes to Apollo Program Specification Revision B were prepared, approved by the Level 1 Change Control Board and published on November 5. Effort continued on the preparation of Revision C of the Apollo Program Specification for publication during the first quarter of 1970 with special emphasis given those sections on the Lunar Roving Vehicle.

Communication Systems

Studies of the performance margins expected for communication between a Manned Space Flight Network Station and a Lunar Module at lunar range were extended to cover worst case parameters for several possible configurations.[15] It was found that: 1) television, telemetry and extravehicular communications system voice with biomedical data transmitted simultaneously from the LM erectable antenna to an MSFN (85 foot) station (or from the LM steerable antenna to a 210-foot station) will be satisfactory only in the LM high transmitter power mode; 2) low bit rate telemetry and baseband voice in the phase modulation mode will be satisfactory in the LM low power mode using the LM steerable antenna and an MSFN station equipped with an 85 foot diameter antenna; and 3) all of the LM phase modulation modes, which provide all communication services except television, will perform satisfactorily at low transmitter power when using the LM erectable antenna to an MSFN station with a 210 foot receiving antenna.

The preceding LM-MSFN communication link analysis was updated using measured Apollo 12 parameters, and the expected performance of the color television transmission from the lunar surface was computed.[16] The results show that the frequency modulated mode with voice originating from inside the LM has the lowest margin because of the lack of speech clipping in the LM audio center. The color television FM mode has the next lowest margin.

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(15) Communications Performance of Possible Apollo (LM) USB Downlink Configurations, Memorandum for File, N. W. Schroeder, October 23, 1969.

(16) Communications Performance of Possible Apollo (LM) USB Downlink Configurations, Memorandum for File, N. W. Schroeder, December 8, 1969.

An analysis was made of the margins for a VHF communication path between the planned Apollo 12 LM landing area and the Surveyor III site, taking diffraction effects into account.[17] It was found that adequate margin was available for communication during EVA to the Surveyor, and that greater margin was obtainable from nearby alternate landing sites (such as actually used).

The performance of the real time command link to an Apollo Lunar Surface Experiments Package (ALSEP) on the lunar surface was computed.[18] Assuming random errors and an average bit error rate of 10^{-6}, the probability that an ALSEP will accept a command in error is 7×10^{-12}; the probability of accepting a good command is 0.99998. The probability of one ALSEP accepting a command intended for another ALSEP (all operate on the same up-link frequency) is on the order of 10^{-18}. A threshold circuit inhibits power to the digital subsection of the ALSEP command decoder in the absence of an up-link signal so that the possibility of noise being accepted as a command in a properly operating ALSEP receiver-decoder is very remote.

Discrepancies between predicted and observed signal strengths from the S-band transponder in the Saturn V Instrument Unit on the Apollo 10 and 11 missions were reviewed.[19] It was concluded that part of the discrepancies were attributable to less favorable antenna look angles than assumed for the predictions, but that a power loss in the system or some other loss mechanism also was indicated. AN MSFC investigation pointed to corona in a coaxial switch, and a design change was made for Apollo 12.

Participation in efforts to solve corona problems in LM communications equipment was continued, and at Center request, technical consultation was provided at meetings with contractors. Recommendations were made regarding pressurization of the S-band power amplifiers and transceivers, and data from tests simulating the lunar mission vacuum timeline were reviewed.[20]

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(17) EVA Communications from Surveyor III Site on Apollo 12, Memorandum for File, I. I. Rosenblum, October 8, 1969.

(18) The Probability of an ALSEP Accepting an Erroneous Command, Memorandum for File, J. E. Johnson, December 1, 1969.

(19) Instrument Unit Command Communications System Anomalies During Apollo 10 and Apollo 11 Missions, Memorandum for File, L. A. Ferrara, October 8, 1969.

(20) Corona in LM Communication Equipment, Memorandum for File, W. J. Benden, October 13, 1969.

A study was made of a deployable hardwire link, similar to that developed for wire-guided torpedoes, as a way to maintain continuous communication between the LM and the astronauts during EVA beyond line-of-sight.(21) It was found that a voice and biomedical data link could be provided at reasonable weight for traverse lengths up to about 15 kilometers, but a television link does not appear feasible.

Methods for the determination of the relative position of an extravehicular crewman (EVC) with respect to the LM on the lunar surface using earth-based or lunar-based tracking systems have been examined and compared.(22) The types of lunar-based tracking systems examined included line-of-sight relay tracking systems and over-the-horizon ground wave tracking systems. Four types of baseline tracking methods from earth were also examined. Determination of the relative position of the LM and EVC on the lunar surface with an uncertainty of approximately 300 meters is possible through the use of earth based tracking techniques if the random uncertainty in the slant range measurements made is no greater than one meter. Actual biases and random error statistics of slant range measurements must be determined before a truly valid estimation of the uncertainty in relative position determination can be made.

Lunar Exploration Design Requirements

A study was completed which compared the effectiveness of various mobility modes for exploration of the Marius Hills, Copernicus Peaks and Hadley-Apennines sites.(23) Representative walking and riding traverses were designed and evaluated for effectiveness in accomplishment of defined scientific objectives. It was found that at these sites the significant science activity of a riding mission was approximately double that of a walking mission due to increase in total traverse distance,

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(21) Astronaut Wire Communication Link During Lunar Explorations, Memorandum for File, W. J. Benden, November 13, 1969.

(22) Determination of the Position of an Extravehicular Crewman With Respect to the LM on the Lunar Surface, TM-69-2034-9, A. G. Weygand, October 23, 1969.

(23) Evaluation of Mobility Modes on Lunar Exploration Traverses: Marius Hills, Copernicus Peaks, and Hadley-Apennines Missions, TR-69-340-4, P. Benjamin, T. A. Bottomley, J. W. Head, M. T. Yates, November 14, 1969.

and number and diversity of sampling stations. It was also found that science return on riding traverses could be increased by relaxing time-in-suit and emergency walkback constraints to allow more efficient use of life support consumables.

It was also found that sites which had scientific objectives located in rilles (Hadley-Apennines) or concentrated in one area (Copernicus Peaks) required linear riding traverses to provide reasonable scientific returns. In these cases, the science return is directly related to LM landing position errors that increase or decrease the distance to the points of interest even with a lunar roving vehicle.(24)

Traverse design nomographs developed in the preceding quarter were further refined and published.(25) These show relationships between traverse length, emergency return constraints, time available for exploration, life support consumables, and time-in-suit in a form which facilitates operational tradeoffs for initial traverse design and system optimization.

Functional requirements for surface navigation in lunar exploration were considered in the context of assumed site terrain characteristics to identify accuracy requirements for crew safety and mission success.(26) It was concluded that prominent landmarks of sites for advanced lunar exploration may permit the crew safety objective of safe return to the LM to be accomplished with minimal or no navigational aids other than a map. For mission success, the primary requirement is for sufficient accuracy to get expeditiously from one identified sampling station to the next.

Functions, requirements, and design alternatives for lunar surface television and communications were reviewed.(27) It was concluded that the TV

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(24) Impact of Off-Target LM Landing on Science Objectives at Hadley-Apennines and Copernicus Peaks, Memorandum to P. F. Sennewald from T. A. Bottomley, October 15, 1969.

(25) Handy Dandy Charts for Determining Operational Constraint Effects in Lunar Traverse Planning, Memorandum for File, P. Benjamin, October 15, 1969.

(26) Position Determination in Lunar Surface EVA, Memorandum for File, P. Benjamin, October 22, 1969.

(27) Requirements for Lunar Surface TV for Apollo 16 and Subsequent, Memorandum for File, J. Z. Menard, November 19, 1969.

needs for lunar science support could be met by a slow-scan high resolution black and white camera using a transmission link with a 500 KHz bandwidth and a moderate size antenna and transmitter. An RF link with the camera was considered to be highly desirable.

Work relating to Lunar Roving Vehicle (LRV) requirements is continuing, with participation in design reviews and the Preliminary Requirements Review. A candidate set of LRV Requirements has been developed for use in discussions with the Centers to reach understanding on content of the Apollo Program Specification, Center level specifications and inter-Center interface control agreements. (28)

Several studies associated with the Lunar Roving Vehicle were initiated. These include the effects of lunar dust on the thermal design of components, an evaluation of the suspension system design, and a means of generating statistical lunar traverses to determine the shock and vibration environment needed to evaluate system performance.

Pressure Vessel Safety Factors

A study of methods for specification and control of pressure vessel safety factors was completed. (29) The study described important Apollo advances in understanding and using pressure vessels. A model specification with refined terminology was proposed as a means to improve control within the limits imposed by the confirmed concepts of Fracture Mechanics. The model has been reviewed with NASA and refinements incorporated. Discussions of specific means of implementing controls have been initiated and a method using existing NASA documentation systems was suggested. (30) A more general list of administrative options for dealing with pressure safety needs was also outlined and evaluated. (31)

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(28) LRV Requirements Review, Memorandum for File, R. D. Raymond, December 12, 1969.

(29) Pressure Vessel Safety Specifications Background and A Proposal for Improvement, TM-69-2032-3, G. W. Craft, November 21, 1969.

(30) Pressure Vessel Safety Discussion at KSC, Memorandum for File, A. D. Cook, G. W. Craft, November 4, 1969.

(31) Four Strategies for Pressure Vessel Safety Control, Memorandum for File, G. W. Craft, December 30, 1969.

Space Vehicle Systems

Work was continued on evaluation of design options for space vehicle systems to meet lunar exploration requirements. A comparison was made of alternatives under consideration for space vehicle modification to extend lunar exploration capability.[32] Using subjectively weighted cost and return factors, it was found that the configuration selected by the Program, including the 5-battery LM, will give a relatively high scientific return with moderate system changes, and will allow flexibility for future improvement by further extension of electrical power system capacity.

An analysis was completed to determine the feasibility of developing and using a "suitcase" solar array that would extend LM payload and stay-time capabilities and also afford a simple LM interface.[33] Using current technology, it was concluded that a rollup array could be developed in 18 months, stowed externally on the LM and deployed on the lunar surface by the astronauts. A 380-watt array would provide a 24-hour increase in stay time at a weight penalty of 85 lbs. A 720-watt array would provide the same increase in stay time and allow the removal of two LM batteries for a net weight savings of 159 lbs.

A study was completed on a proposal to increase usable LM propellants by removing balance lines from the paired descent propellant tanks.[34] It was shown that without the balance lines a flow rate differential between the tanks would tend to decrease usable propellants. These findings were accepted and the orificing of feed lines was introduced to obtain a balanced flow. Study of the response of this system to fuel sloshing and its impact on usable propellant is continuing.

An analysis was made of alternatives for satisfying life support system emergency return requirements with feasible combinations of existing or developmental components. The preferred configurations were found to be the currently planned primary and secondary life support systems (i.e., the -7 PLSS and SLSS) and the -7 PLSS modified for buddy system use, with the Oxygen Purge System. While the latter combination offers significant weight savings, the

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(32) LEP System Configuration Selection Evaluation, Memorandum for File, R. D. Raymond, October 14, 1969.

(33) "Suitcase" Solar Array System for LM Payload and Staytime Extensions, Memorandum for File, R. D. Raymond, November 24, 1969.

(34) Status of LM Descent Propellant System Mass Related Problems, Memorandum to R. V. Sperry from D. M. Duty and S. S. Fineblum, October 14, 1969.

emergency return capability may be limited by non-linear effects in carbon dioxide and thermal control, and further evaluation is required.[35]

An effort has been initiated to assist NASA in evaluating the ultraviolet radiation protection required and the protection actually provided to Apollo astronauts during extravehicular activities.[36] Physiological limits and visor test results are being reviewed to determine the need for operational constraints to control the maximum exposure to ultraviolet radiation.

Work was continued on a review of Saturn V structural safety factors with J-Mission payload increases.[37] Flight data show some structural temperatures to be significantly lower than predicted, and this may permit some reassessment of the existing safety factors.

Effort continued on space vehicle structural and dynamic modeling, with emphasis on the S-II as a result of the oscillation experienced on the Apollo 12 mission. Spectrum analyses of a number of Apollo 12 space vehicle measurements were generated and furnished to the Flight Evaluation Working Group and the Pogo Working Group at MSFC.[38] The S-II structural model has been improved by refinement of the thrust structure representation and incorporation of a multi-degree-of-freedom model of the propellant tank liquid-shell interface. Analyses of the S-II LOX suction line test facility confirm the validity of the MSFC model of the suction line, and show the second resonance of the LOX line with accumulator to be at 50Hz rather than 30Hz as previously thought.[39,40]

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(35) Comparative Analysis of Life Support Systems for Emergency Return During Lunar EVA, Memorandum for File, T. A. Bottomley, December 19, 1969.

(36) UV Radiation Exposure During Lunar EVA, Memorandum to P. F. Sennewald from T. A. Bottomley, November 24, 1969.

(37) Saturn V Increased Payloads — Booster Factors of Safety, Memorandum for File, W. C. Brubaker, October 13, 1969.

(38) SA-507 (Apollo 12) Spectrograms, Memorandum for File, R. V. Sperry, December 1, 1969.

(39) Presentation Made to the S-II POGO Working Group Meeting, Memorandum for File, A. T. Ackerman, October 20, 1969.

(40) MSFC POGO Working Group Meeting, Memorandum for File, A. T. Ackerman, J. J. O'Connor, R. V. Sperry, December 23, 1969.

POGO stability analyses now correspond closely to flight results, and show that the addition of a center engine LOX suction line accumulator on the S-II would significantly improve the stability.

Work was initiated to simulate the loads during the launch phase of a space vehicle. A rigid body simulation with pitch-plane motion has been completed which accounts for lateral wind effects, drag, control system response and engine gimbaling.

APOLLO/SATURN SYSTEMS ENGINEERING
SCIENTIFIC STUDIES

Site Selection

Presentations at the October meeting of the Group for Lunar Exploration Planning included a lunar science rationale, the philosophy of site selection, and a geological description of the sites which had been previously selected.(41,42) The meeting resulted in the reapproval of original sites with alternates provided for Tycho and Fra Mauro.

Geologic studies of the lunar exploration landing sites continued during this quarter. A paper on landing site characteristics was presented at the American Geophysical Union meeting.(43)

Apollo 12

Studies of lunar landing site photography included a plan for the Apollo 12 mission in the event a landing could not be made.(44) This work is being continued for the future missions.

An evaluation was made of the exploration site photography obtained on Apollo 12 using the bracket-mounted Hasselblad camera and rotation of the spacecraft for image motion compensation (IMC).(45) This evaluation concluded that the 500 mm lens did not provide the desired resolution. Recommendations

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(41) Lunar Science Rationale, Presentation to The Group for Lunar Exploration Planning, Manned Spacecraft Center, N. W. Hinners, October 16, 1969.

(42) Lunar Exploration Sites, Presentation to The Group for Lunar Exploration Planning, Manned Spacecraft Center, F. El-Baz, October 16, 1969.

(43) Characteristics of the Apollo Lunar Landing Sites, Paper presented at the American Geophysical Union Meeting, San Francisco, California, December 15-18, 1969, F. El-Baz.

(44) "Bootstrap" Photography Under a No LM Landing Contingency on Mission H-1, Memorandum for File, R. A. Bass, October 23, 1969.

(45) Apollo 12 Exploration Site Photography, Memorandum for File, F. El-Baz, December 17, 1969.

were made to obtain photography of Descartes on a subsequent mission and to drop Lalande as an alternate to Censorinus, since Lalande is very rough and undulating.

An analysis of the Modulation Transfer Function curves of the 500 mm f/8 lens carried on Apollo 12 showed it to be inferior in quality to the 250 mm f/5.6 lens which had been carried on previous Apollo missions.[46] The ground resolution obtainable with the two lenses is virtually the same, in spite of the greater magnification obtainable with the longer focal length.

Bellcomm participated on real time support teams for photography, visual observations and locating the map coordinates of the landed LM during the Apollo 12 mission.[47] A recommendation for increased interaction between the crew and the science support team will be implemented by the generation of a Detailed Objective for visual observations on future missions.

Apollo 13

Bellcomm participated in briefing the prime and back-up crews for Apollo 13 on lunar geology, photography, visual observations, and familiarization with the landing site. The prime Command Module Pilot was briefed on orbital science.

Bellcomm participated in the selection of a set of photographic targets for inclusion in the Apollo 13 flight plan. This will be the first mission for which such targets are scheduled in the timeline rather than as "targets-of-opportunity".

A Detailed Objective was prepared to provide for a set of visual observations from lunar orbit on Apollo 13. This Detailed Objective would allow for training of the astronauts in the recognition of lunar surface features and their salient characteristics.

During LM touchdown on Apollo 12, more dust was observed than during the Apollo 11 landing. Bellcomm arranged and participated in a meeting to discuss the lunar geological, soil mechanics, and remote sensing data as they pertain to LM descent engine induced surface erosion and specifically how they will affect Apollo 13.

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(46) Apollo 12 Telephoto Lens Quality, TM-69-2015-7, H. W. Radin, December 19, 1969.

(47) Apollo 12 Science Support, Memorandum for File, F. El-Baz, December 11, 1969.

Ground-Based Apollo Photography

Nominal pointing angles for the Apollo 12 spacecraft were generated for the professional and amateur astronomers who were providing optical coverage of the spacecraft and its waste water dumps. Real time corrections to these pointing angles were calculated during the mission and transmitted to major observers. A number of successful observations were made including, for the first time, ground-based photographs of a waste water dump from the spacecraft fuel cells.[48] These will augment data previously obtained for an assessment of the interference caused by such contaminants to optical observations from spacecraft.

Lunar Science

Examination of the Apollo 10 and 11 photographs of the lunar farside resulted in the discovery of features which were interpreted as "Lunar Igneous Intrusions". A report was issued describing these features and emphasizing their importance.[49] An earlier version of the report will be incorporated in the Apollo 10 Science Report.

A detailed study of the young crater Aristarchus is being undertaken in order to provide a model for the origin and evolution of other lunar impact craters and associated deposits. A paper on the crater Aristarchus was presented at the American Geophysical Union meeting.[50]

Lunar Surface Science

Results from the Apollo 11 Dust, Thermal and Radiation Engineering Measurements experiment (DTREM I) were submitted for incorporation in the

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(48) Photography of Apollo 12 Waste Water Dump - Preliminary Report, Memorandum for File, J.O. Cappellari, Jr. , W.I. McLaughlin, December 30, 1969.

(49) Lunar Igneous Intrusions, TR-69-340-5, F. El-Baz, December 3, 1969; also published in "Science", January 2, 1970.

(50) Distribution and Interpretation of Crater-Related Facies: The Lunar Crater Aristarchus, Paper presented at the American Geophysical Union Meeting, San Francisco, California, December 15-18, 1969, J.W. Head.

90-day mission evaluation report. Six data tapes, which included measurements from the precision nickel resistance thermometer, were received prior to termination of the experiment. A computer program is being prepared to support the data analysis from which will be derived the relationship between sun angle and surface temperature.

Approximately seventy-five proposals for lunar surface science on Apollo 16 through Apollo 20 were reviewed for technical content. These reviews were offered in support of a formal experiment evaluation conducted at MSC in December.

An evaluation was begun to provide for selection of the most suitable type of lunar surface mass spectrometer that could be used to determine the constituents of the lunar atmosphere. A study of the possible types of suitable mass spectrometers was completed.(51)

Lunar Orbital Science

Bellcomm participated in the Headquarters Orbital Science Task Team which assessed requirements for the design and qualification of the Sounding Radar, the Alpha-Particle Spectrometer and the X-Ray Spectrometer. Assistance was also provided for the timeline scheduling of data acquisition periods for the various lunar orbital experiments.

Bellcomm representatives were appointed to the newly-formed Apollo Orbital Science Photographic Team. This team will assist in the selection and approval of photographic systems to be flown on future Apollo missions, the planning for photography, and the evaluation of the data acquired.

Certain parts of the west front face of the moon are in view of Apollo spacecraft only under earthshine illumination during the planned Apollo missions. Earthshine photography of scientific targets in these regions was proposed.

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(51) Development Status of Lunar Mass Spectrometers, Memorandum for File, G. K. Chang, October 3, 1969.

A presentation on the Lunar Multispectral Photography experiment was given at the Apollo 12 news conference on November 13 by the Principal Investigator from Bellcomm.[52] Data returns from the Apollo 12 mission included 142 frames in each of three colors and 105 frames in infrared photography. From the photographs, one two-color computer composite of the Fra Mauro formation (including the Apollo 13 landing site) will be obtained for incorporation in the Apollo 12 Preliminary Science Report.

A study was performed to assess whether the Apollo 11 science results may have changed the scientific significance of the Solar Wind Mass Spectrograph (SWMS) and whether the priority of the experiment should be increased relative to the other orbital experiments. Based on the Apollo 11 preliminary sample analysis, it was concluded that no new information had been acquired which increased the significance of the SWMS to lunar science, and a recommendation was made to retain the experiment priorities.

A recommendation was made that the downlink Bistatic Radar Experiment, originally scheduled for Apollo 19 and Apollo 20, be performed on earlier missions.[53] Such reassignment would permit more data acquisition time for the other experiments on Apollo 19 and 20, determination of the Brewster angle and surface roughness at S-band of areas of the moon which may not be over-flown on subsequent missions, and an assessment of the desirability of performing the experiment on subsequent missions. The S-band portion of the experiment has now been assigned to Apollo 14 and 15. The use of the CSM VHF signal as part of a Bistatic Radar Experiment was also suggested as an addition to the S-band experiment. The addition of the VHF portion of the experiment would permit the acquisition of significant geological information (such as thickness of the regolith) which would not otherwise be obtained.

The need of the Parkes 210 foot dish in addition to the Goldstone Mars 210 foot dish for the Bistatic Radar Experiment was evaluated. It was pointed out that the Principal Investigator has requested only one 210 foot dish (preferably the Goldstone Mars site) and that, in addition, the Parkes site was not properly

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(52) Principal Investigator Statement on the S-158 Lunar Multispectral Photography Experiment, Presentation given at the Apollo 12 News Conference held at Kennedy Space Center, November 13, 1969. A. F. H. Goetz.

(53) Implementation of the CSM Lunar Orbital Bistatic Radar Experiment on an Early Apollo Mission, Memorandum for File, W. L. Piotrowski, December 9, 1969.

instrumented to be of use in the Bistatic Radar Experiment. It was suggested, therefore, that no further consideration be given to use of the Parkes site for the current Bistatic Radar Experiment.

The presence of possible contaminants surrounding the CSM was investigated and means for measuring these contaminants using the CSM cameras and instruments in the lunar orbital experiments package were suggested to the Apollo Program Office. Steps have been taken to implement photographic experiments on Apollo 13 to measure the degree of contamination. Results of this effort may have a bearing on the conduct or interpretation of certain orbital experiments.

Lunar Mapping

The problem of determining lunar elevation from surface slope data using the photometric function has led to a suggestion for a two-dimensional electro-optical integrator which could serve as a building block for a two-dimensional analog computer.[54] A possible way of dealing with the non-linearity of the photometric function was suggested.

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(54) Concept for a Two-Dimensional Analog Integrator, with Application to Slope-to-Height Conversion, Memorandum for File, H. W. Radin, November 18, 1969.

Weight Reporting

Weight and performance reporting for the dry workshop configuration was initiated. Reports for the months of November and December were summarized for the AAP Director and issued.

Mission Sequence

The advisability of using an "astronaut day" with a 23.5-hour duration in place of the natural 24-hour day during the first AAP mission was studied. Factors considered were: (a) launch and recovery opportunities, (b) spacecraft/ground communications, (c) extravehicular operations, (d) crew preference, (e) physiological effects, and (f) effects on medical monitoring experiments. The principal advantages of a 23.5-hour crew "day" were found to be:

1. The astronauts would be awake during all periods of frequent communications contact with the ground,

2. Favorable opportunities for performing EVA's occur on each mission day, thereby providing maximum scheduling flexibility, and

3. No phase shift in in-flight sleep patterns is required for nominal launch and recovery.

Disadvantages include possible difficulties in astronaut adaptation to the unusual time routine, possible interference with a critical medical experiment, lack of synchronization with normal mission control work shifts, and the probable need of preflight astronaut training to determine individual adaptability. In view of these considerations, it was recommended that a 24-hour astronaut day be retained in AAP.(55)

Time estimates for experiments that require participation by the flight crew were reviewed. It was found that documented estimates exist for only 27 of 35 such experiments assigned to the first AAP mission. Three experiments were identified which together account for more than 50% of the total known experiment man-hour requirements; twelve experiments account for

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(55) Crew Sleep Cycles During the First AAP Mission, Memorandum for File, D. J. Belz, November 17, 1969.

more than 90% of that requirement. It was recommended that major uncertainties in these relatively time-consuming activities be resolved early in the development of mission operational plans. [56]

The BCMASP Earth Orbit Simulator (EOS) was modified to run on the UNIVAC 1108 computer system under EXEC 8 software. In addition, other changes were made to expand the capabilities and to increase the operational flexibility of the simulator. EOS now computes a spacecraft ephemeris, spacecraft day/night cycles, photographic target-site visibility, line-of-sight encounters with MSFN ground stations, and an optimum powered flight trajectory.[57]

Program Specification

Work continued on updating the Program Specification. The most significant action was approval and publication of requirements for 24 of the AAP experiments.

Structures and Dynamics

Continued weight growth in the AAP-1 payload led to some concern by the program office that two Apollo Telescope Mount (ATM) control moment gyros would not be able to control the vehicle in the solar inertial attitude. An analysis of current Saturn Workshop (SWS) inertial properties showed that an additional 25% growth in the difference between maximum and minimum principal moments of inertia is permissible before exceeding the control capability of the two CMG's. [58] Assuming an unchanged geometrical mass distribution, the SWS weight can, in fact, grow to the Saturn V payload capability for a 235 nm, 50° inclination orbit without exceeding the control capability.

The Analytical Spacecraft Docking Simulation employing impulse-momentum techniques and current SWS and CSM mass properties was used to analyze the

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(56) Preliminary Crew-Time Estimates for AAP-1/AAP-2 Experiments, Memorandum for File, B. H. Crane, December 2, 1969.

(57) Revisions to the BCMASP Earth-Orbit Simulator Program, Memorandum for File, A. B. Baker, November 10, 1969.

(58) AAP Cluster Mass Properties and CMG Control Capability, Memorandum for File, W. W. Hough, November 20, 1969.

CSM-to-MDA docking dynamics.(59) Successful docking of the present AAP vehicles appears feasible. The study indicates that the probability of success can be increased by reducing the initial miss distance, offset angle, lateral velocity and angular rate of the CSM relative to the SWS. An increase in initial axial velocity, within the limit of the specification of 1.0 fps, is especially effective. Axial thrusting of the CSM, initiated when the probe head contacts the drogue, virtually ensures capture.

A method was developed to determine the response of simply supported, finite Timoshenko beams under any general time and space dependent loading.(60) Simply supported end conditions permit the use of finite Fourier transfer methods which, when coupled with the Laplace transform techinque, lead to a relatively straightforward solution. The general solution was used to solve the problem of a suddenly applied, concentrated load at the beam mid-span. Application to other structural vibration problems, such as deformation of space telescopes due to impulsive loading, is straightforward.

The development of lumped parameter dynamic structural models of the AAP modules has been initiated. Preliminary models of the SWS, SWS solar arrays, Airlock Module (AM), and Multiple Docking Adapter (MDA) have been completed.(61) The modal frequencies compared favorably with results from an analysis made by Martin Marietta, Denver, using a similar configuration, but for the wet workshop. Current effort is to model the ATM, ATM solar arrays, and ATM deployment assembly, and to update early module models to represent the present configuration better. The AAP payload weight growth and its implications on the Saturn V launch vehicle is being monitored; of particular concern is the I. U., S-IVB forward skirt, and the S-IVB liquid hydrogen tank cylinder. Preliminary structural design criteria for the OWS were reviewed in depth and discussed with MSFC.

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(59) AAP Docking Simulation, Memorandum for File, R. J. Ravera, December 11, 1969.

(60) Response of Simply Supported Timoshenko Beams, TM-69-1022-11, R. J. Ravera, November 14, 1969.

(61) Orbital Workshop Vibration Analysis, Memorandum for File, H. E. Stephens, October 21, 1969.

Command and Service Module Venting

A presentation was made to the AAP Program Director on the relationship between the indexing of the CSM to the SWS and the CSM vent locations.[62] This study was stimulated by a Center proposal to re-index the CSM by approximately 180° to permit alignment of the CSM inertial platform while maintaining the AAP cluster in the solar inertial attitude. The result showed that re-indexing by 180° would cause three CSM vents — the water boiler vent, the urine dump, and the waste water vent — to be pointed directly at the ATM when the vehicles are docked. It is not planned, however, to use the first two vents when docked, and use of the waste water vent is possible only if the CSM fuel cells are kept in operation after docking. Waste water can also be eliminated by manual transfer to the S-IVB LOX tank disposal volume.

Thermal System Studies

A detailed, 430-node model of the ATM Charger-Battery-Regulator-Module was reduced to a simple, equivalent circuit of seven nodes. This simple model saves computer time and approximates temperatures of the detailed model to about 5° F.

An equivalent circuit method for the Command Module was developed and will be used to study interactions of the MDA-CM atmosphere exchange, glycol loop, cabin heat exchanger, radiators, and the external environment.

Work continued on improving and expanding the utility of the AAP Orbital Assembly Heat Transfer Computer Program. The program has been checked out and the output correlated with other analytical results.

All thermal computer programs were converted from EXEC 2 to EXEC 8. An EXEC 8 version of the large thermal analyzer program (CINDA) was obtained. Because CINDA is so widely used by the Centers and contractors, errors found and corrected during the trial period were documented.[63]

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(62) Presentation to ML Staff Meeting of November 19, 1969 — CSM Vent Locations, Memorandum for File, J. J. Sakolosky, December 1, 1969.

(63) Edits to Univac 1108 EXEC 8 Version of CINDA, Memorandum for File, B. W. Lab, October 29, 1969.

Experiments

A review was made of the plans for implementing AAP Experiment M479, Zero-g Flammability. Recommendations were made to NASA in the areas of experiment procedures, hardware design, and the use of color IR film so that more quantitative experimental data can be obtained. (64)

A study of two AAP medical experiments, Mineral Balance (M071) and Bioassay of Body Fluids (M073), resulted in a food packaging and eating strategy which satisfies both the nutritional requirements of the experiments and the eating habits of the crews. (65) It was recommended that all food items be divided into a small number of categories, the individual items in each category identical with respect to certain constituents of interest. In any 24-hour period, each crewman would select and consume a predetermined number of items from each category. Pure carbohydrate would be consumed to adjust the caloric intake to a value required for maintaining body weight.

Communications Studies

The results of modifying the current design of the AM and ATM communications systems in order to provide a more integrated system were evaluated. (66) The two systems proposed by MSFC were (1) a single S-Band command system to replace the two existing UHF systems, for use by both the AM and ATM, and (2) a complete two-way S-Band System, similar to that in the CSM. These alternatives were intended to reduce the operating costs of the ground network by eliminating the requirement for both UHF (command) and VHF (telemetry) support facilities. It was found that neither system provided significant cost savings because these facilities are needed to support other programs.

Alternative configurations of a communications satellite (Intelsat IV) terminal for the SWS that would provide voice and data relay to and from

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(64) Comments on Zero Gravity Combustion Tests, Memorandum for File, M. V. Drickman, December 3, 1969.

(65) Comments on the AAP Experiments M071 and M073, Memorandum for File, L. D. Sortland, October 31, 1969.

(66) Discussion of Proposed Changes to the Communications Systems of the AM and ATM in AAP, Memorandum for File, A. G. Weygand, October 10, 1969.

the SWS and earth were analyzed.[67] A program decision was subsequently made not to incorporate this terminal on the first SWS.

To assist in determining electrical power requirements for the AAP CSM's, the interfaces between the CSM and the AAP Experiments D008 (Radiation in Spacecraft), S071/072 (Circadian Rhythm Pocket Mice/Vinegar Gnat), and S061 (Potato Respiration) were examined.[68] The results show that the CSM S-Band power amplifier will probably be used each time the data are dumped to an MSFN station. Experiment D008 uses the CSM data storage equipment and the USB-FM transmitter which is hard wired to the S-Band power amplifier. The other experiments, S071, S072, and S061, have their own data storage which is read out through the high bit rate telemetry format of the CSM. Performance margins for high bit rate at maximum slant range between the CSM and the MSFN station require that the power amplifier be used. If experiment data read out is restricted to short slant range passes over MSFN stations, however, the low transmitter power mode could be used. Acceptable slant ranges will be determined when radiation patterns for the orbital configuration become available.

Lightning Expectancy at AAP Launch Pad

Estimates of lightning strokes were made for the Saturn Workshop launch vehicle, assuming a six-week pad exposure.[69] The data show an expectancy of 1.3 strokes per launch during the summer months. The "cone of protection" concept indicates that the vehicle should recieve significant protection from the umbilical tower.

Second Workshop Planning

Bellcomm participated with MSFC in a study of the capability of a second Saturn Workshop (SWS-II) to support a stellar telescope. A telescope with an

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(67) Implementation of an Intelsat IV Terminal on the SWS (Apollo Applications - 1), Memorandum for File, R. L. Selden, October 22, 1969.

(68) Interfaces Between AAP Experiments D008, S061, and S071/072 and the Communications System of the AAP CSM's, Memorandum for File, A. G. Weygand, November 18, 1969.

(69) Lightning Expectancy and Protection for AAP Launches, Memorandum for File, W. O. Campbell, October 14, 1969.

aperture of 72 inches is the maximum that can be accommodated by the ATM gimbal system. A system concept and the means for integrating such a telescope were considered.(70)

A summary of the results to date of MSC and MSFC studies on an artificial gravity experiment was presented to the Deputy Associate Administrator, OMSF, on December 11.

A design concept for SWS-II was presented to the Apollo Applications Program Director.(71) The concept, based on principles believed basic to space station configuration design, provides a basis for initiating the design while maintaining a capability to absorb new requirements with a minimum of configuration impact.

Attitude Control Studies

A study was completed on the use of magnetic torque for CMG momentum management.(72) Magnetic torque is developed by a controlled magnetic dipole that reacts with the earth's magnetic field. It was shown that system implementation would require only the addition of a magnetometer to measure the earth's magnetic field, an electromagnet to produce the magnetic dipole, a control amplifier to supply the proper current to the magnet coils, and a small amount of digital computer software. Operation would be automatic and momentum dump attitude maneuvers would be elminated.

A magnetic moment control law was devised which closely approximates the one that requires minimum electrical energy from the power system. Minimum weight magnetic design equations were developed and actual air coil and iron core coil magnet designs were made for a second workshop.

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(70) Stellar ATM on Second Saturn Workshop, Memorandum for File, G.M. Anderson, October 17, 1969.

(71) Design Concept for Dry Workshop II, Memorandum for File, G.M. Anderson, November 10, 1969.

(72) Use of Magnetic Torque for CMG Momemtum Management, TM-69-1022-8, W. Levidow, December 29, 1969.

Design Reviews

Bellcomm personnel attended and provided technical support for all sessions of the Cluster System Design Review held at MSFC December 2-4, 1969. Presentations summarizing the results of structural, electrical, thermal and attitude control sessions were made to the Headquarters AAP staff.

ADVANCED MANNED MISSIONS SYSTEMS ENGINEERING

Program Requirements

Integrated Space Program - Continued support was provided for the Office of Manned Space Flight. Draft documents on Program objectives and accomplishments, flight hardware concepts, and mission modes were revised and expanded.

Mission Analysis

Integrated Space Program/Propulsion Stages - The commonality of propulsion stage requirements for the U.S. Air Force Orbit-to-Orbit Shuttle (OOS) and NASA LM-B propulsion module was examined.[73] Areas considered were propulsive performance, dimensional compatibility with the space shuttle, and structural design requirements. Differences in launch loads and space flight environments were also evaluated. These analyses showed that the USAF and NASA mission profiles are quite different and that complete commonality of hardware is not possible. Some commonality may be possible using kit form modification to a basic vehicle design.

Integrated Space Program/Lunar Shuttle - Several techniques for using the earth-to-orbit shuttle as a temporary substitute for a nuclear lunar shuttle were investigated.[74] It was demonstrated that the use of tip tanks on either two-stage or stage-and-one-half concepts would permit the earth-to-orbit shuttle to function as a lunar shuttle. However, the recurring operating costs for such a mission mode would be at least double that for the nuclear stage lunar shuttle.

Satellite Servicing - Transfer velocities between space stations and independent satellites were studied to determine propulsion requirements for

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(73) Use of Proposed Air Force Orbit-to-Orbit Shuttle (OOS) in NASA's Integrated Space Program, Memorandum for File, A. E. Marks, December 10, 1969,

(74) Two-Stage, Fully Reusable Space Shuttle Lunar Mission Capability, Memorandum for File, W. H. Eilertson, October 27, 1969.

satellite servicing operations.[75] It was shown that minimum ΔV requirements (those determined by considering orbital inclination and altitude differences only) are not representative. Differential nodal regression rates due to earth oblateness cause required transfer velocities to exceed the minimum and to oscillate with time. Therefore, the frequency and duration of satellite accessibility are determined by the ΔV available. Computational results for representative space station and satellite orbits were presented.

Role of man - A paper on the use of man in space, based on previously reported work, was presented at the AIAA Sixth Annual Meeting.[76]

Project Tektite - A presentation of research associated with Project Tektite I described how underwater saturation habitats can be used to provide information for mission planning and human engineering of manned space flight.[77] The key elements provided by such habitats are 1) the real hazards and natural confinement produced by the undersea environment and decompression constraints, and 2) the necessary and significant work to be done in such habitats. The project emphasized observation and data collection with minimal interference of crew activity. The observational methodology developed is being extended for use in Project Tektite II.

Configuration Studies

Attitude Control - The problem of attitude control of a mass-unbalanced, axially-symmetric space station consisting of a rotating artificial gravity section

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(75) Transfer Velocities Between Earth Space Stations and Satellites, Memorandum for File, H. B. Bosch, November 24, 1969.

(76) Use of Man in Space, Paper No. 69-1045 presented at the American Institute of Aeronautics and Astronautics 6th Annual Meeting and Technical Display, Anaheim, California, October 20-24, 1969. B. T. Howard, G. T. Orrok.

(77) Applications of Behavioral Research on Undersea Habitats to Manned Space Flight, Paper No. 69-1120 presented at the American Institute of Aeronautics and Astronautics 6th Annual Meeting and Technical Display, Anaheim, California, October 20-24, 1969. N. Zill (Bellcomm), S. Deutsch, E. J. McLaughlin, E. S. Burcher (NASA).

and a despun section was investigated.[78] It was shown that the amplitude of the conical precession of the spin axis can be minimized by proper design. First, the design should be such that the ratio of the axial moment of inertia of the spinning section to the transverse moment of inertia of the space station be as large as possible. This implies that the despun section be much smaller than the spinning section and that the space station present a low, flat silhouette when viewed from a direction normal to the spin axis. Second, the crew compartments and compartments to and from which equipment is to be shifted should be situated as close as possible to the space station mass center. In addition, it was concluded that for very large satellites the use of control moment gyros is an impractical way to reduce the coning motion.

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(78) Problems in Attitude Control of Artificial "G" Space Stations with Mass Unbalance, TM-69-1022-12, R. A. Wenglarz, December 23, 1969.

MISSION OPERATION STUDIES

The design of the voice communications system at KSC was reviewed, as used for prelaunch tests and launch. Recommendations were made for improving the systems performance and reliability including the removal of voice operated devices and isolation of the long lines to KSC from the Mission Control Center.(79) The performance of the system was monitored during the prelaunch tests and launch for Apollo 12.(80,81) Some problems, including noise bursts on certain Operational Intercommunication System (OIS) channels, noisy radio links with the spacecraft, and variations in voice signal levels on certain OIS channels were observed during FRT. The performance improved for the Apollo 12 CDDT and the system supported the launch quite adequately.

The VHF and USB coverage provided by four configurations of MSFN stations was calculated for 56-day AAP missions having orbital plane inclination angles of 35° and 50°.(82) Results indicated that an MSFN station in southern South America would be very effective as a coverage gap filler for both plane inclinations. Adding a VHF capability to the MSFN USB stations with 85 foot diameter antennas makes very little change in the VHF coverage gaps.

A parameter of interest in the performance of the Apollo Unified S-Band System is the time to next cycle slip, $\hat{T}$, in the coherent receivers used in the system. Cycle slipping contributes to both the noise in the tracking data as well

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(79) Review of Voice Operated Devices in Pre-Launch Communications at KSC, Memorandum for File, J. T. Raleigh, October 13, 1969.

(80) Voice Communications Monitoring at KSC During Apollo 12 FRT, Memorandum for File, L. A. Ferrara, October 28, 1969.

(81) Voice Communications Monitoring at KSC During Apollo 12 CDDT, Memorandum for File, L. A. Ferrara, November 7, 1969.

(82) Study of Four MSFN Configurations for Coverage of 56 Day AAP Mission, TM-69-2034-10, J. P. Maloy, December 31, 1969.

as the performance of the voice and data channels. An analysis was performed to determine analytically the statistics of $\hat{T}$ for both first and second order phase lock loops.[83]

An investigation of the relative performance of coding techniques which are applicable to manned space flight communication systems has been undertaken. Preliminary results indicate that convolutional codes can increase channel capacity by a factor of two or three over a similar uncoded channel.

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(83) Time to Cycle Slip in First and Second Order Phase Lock Loops, TM-69-2034-8, L. Schuchman, December 19, 1969.

SPECIAL TASK ENGINEERING STUDIES

Manned Space Flight Experiments Program Studies

Task Order No. 34

The temperature and size distribution of liquids in space was studied.[84] Micron-size droplets of liquid H_2, O_2, and H_2O released in space during normal operations on Apollo lunar missions quickly freeze and reach equilibrium where the loss of energy from sublimation and emission of radiation just equals the absorption of radiation that is incident from the earth and the sun. It was found that for H_2 and O_2 the rate of emission of radiation is negligible compared to the rate of sublimation, but for H_2O, emission is very important and increases particle lifetimes significantly. Typically, at an altitude of 400 miles, where the earth is an important infrared source, sunlit particles decrease in radius by a factor of "e" with a time scale of 15 seconds for H_2, 120 seconds for 0_2 and 1200 seconds for H_2O. In cislunar space these times were shown to increase roughly by an order of magnitude. The accuracy of the results for H_2 and O_2 is limited by experimental uncertainties in the imaginary part of the index of refraction for these materials.

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(84) The Temperature and Size Histories of Liquid H_2, O_2, and H_2O Particles Released in Space, Paper presented at the American Geophysical Union Meeting, San Francisco, California, December 15-18, 1969. A. C. Buffalano, R. D. Sharma.

SPECIAL TASK ENGINEERING STUDIES

Analysis of Haze Effects on Martian Surface Imagery

Task Order No. 35

In support of Bellcomm's role as Principal Investigator on the Mariner Mars '71 television experiment, mission analysis studies are being conducted to aid in defining an operational plan to investigate variable features of the Mars surface and atmosphere. In one study, a set of graphical overlays was produced which allow the mission analyst who is planning photographic experiments to determine rapidly the viewing and illumination angles of any region of the surface from any point in orbit during the nominal 90 day mission.[85] The reference orbit for this study is inclined 50° to the Mars equator, and has a period of 32.877 hours and a periapsis altitude of 1600 kilometers. This orbit period, which is close to 4/3 of the Mars rotation period, was selected to provide repetitive photography of the same areas throughout the mission with minimum changes in lighting and viewing angles.

Using the above overlays to determine a preliminary photographic sequence plan, a second study outlined a more detailed plan.[86] By specifying the time when each picture was taken and the camera pointing angles, coverage of the pictures on a map of Mars was automatically produced.

Repetitive photography of the same surface areas under high sun (near local noon) illumination conditions is feasible in a number of areas where the maximum change in illumination and viewing angles over the nominal 90 day mission is less than 10 degrees.

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(85) Illumination and Viewing Conditions Encountered by the 1971 Mars Mariner TV Experiment, Memorandum for File, G. A. Briggs, October 31, 1969.

(86) Mars Mariner '71 Variable Surface Features Television Experiment: Preliminary Footprints for Selected Revolutions of the B Mission Orbit, Memorandum for File, G. A. Briggs, December 16, 1969.

Long Range Planning

Support for the NASA Planning System continued. A point of view for a rationale and methodology for structuring long range and alternative near term Agency program plans was developed and its application to the post-Apollo period illustrated.[87] In addition, observers on the Planning Steering Group participated in the identification of 1) elements of the NASA Long Range Plan that require further technical analysis, and 2) technical activities necessary in the next Agency program planning cycle.

Scientific Studies

Venus Radio Interferometer Experiment - The interferometric observations of Venus performed during the Spring, 1969 inferior conjunction confirm the small 12° K equator-to-pole temperature difference and show a small asymmetry in the brightness around the equator. This asymmetry was most pronounced near inferior conjunction and amounts to a difference of 18.4 ± 9.2° K between the sunset and dawn limbs.[88] The observed limb brightening can be attributed to the effect of an atmosphere with a substantially sub-adiabatic lower region, and composed of ~95% carbon dioxide and less water vapor than deduced from Venera 4 results.

Meteoroids - The evolution of the sporadic and shower meteoroid equilibrium population from a source with a given mass distribution under the influence of collisional and radiative processes was examined.[89] The theoretical results agree with the observed radio shower meteor distribution, provided the

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(87) Long Range Space Program Planning, TR-69-105-2-1, M.M. Cutler, J.P. Jamison, H.H. McAdams, W.J. McKune, J.E. Volonte, C.P. Witze, October 6, 1969.

(88) First Results from Radio Interferometric Observations of Venus, Memorandum for File, W.A. Gale, M. Liwshitz, A.C.E. Sinclair, November 28, 1969.

(89) On the Evolution of the Meteoroid Population, Paper presented at the American Geophysical Union Meeting, San Francisco, California, December 15-18, 1969, J.S. Dohnanyi.

population index of sporadic meteors equaled about 13/6. The dominance of collisional processes in determining the mass distribution of photographic and radio meteors was established and the effect of radiation pressure on the shape of the distribution was shown to be significant.

Manned Planetary Missions - A survey of opportunities for conjunction class manned missions to Mars from 1974-1993 was made.(90) Total trip time is 1000 ± 100 days over all conjunctions studied. Time in Mars orbit varies from 320 days to 540 days. For the reference mission chosen, the initial mass in earth orbit varied from 2.6 to 3.2×10^5 lbs over the ten opportunities studied.

Technological Studies

Space Transportation Costs - A study was conducted to determine factors influencing the unit costs of expendable tankage for partially reusable and expendable space transportation systems.(91) Among the factors considered were production quantity and rate, design and fabrication techniques, materials selection, and transportation. It was determined that the most significant factors governing tank unit cost are production rate and quantity and tank design complexity. Materials and transportation costs were found to be less significant by comparison.

Cryogenic Storage - A study was made of problems associated with boiloff during long term storage of cryogenics in space.(92) Weight penalties associated with propellant boiloff and active refrigeration systems were evaluated for representative missions and propulsion stages. It was found that boiloff from propellants stored in advanced design cryogenic tankage would not be sufficient to compromise the feasibility of the missions considered. Weight savings could be realized in some cases, particularly for an earth orbital liquid hydrogen storage facility, if solar powered refrigerators were provided to reduce or eliminate propellant boiloff.

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(90) IMEO Requirements for Conjunction Class Manned Missions to Mars, 1974-1993, Memorandum for File, C. L. Greer, November 24, 1969.

(91) Assessment of Expendable Tankage for Low Cost Transportation Systems, Memorandum for File, A. S. Kiersarsky, November 5, 1969.

(92) Active Refrigeration for Cryogenic Storage in Space, Memorandum for File, D. J. Osias, December 30, 1969.

Space Shuttle - A summary of space shuttle technology issues that will require concentrated research and development effort to achieve a system with low operating cost was prepared.[93] Among the areas identified were aerodynamics, structures and materials, propulsion, integrated electronics, and human factors.

Digital Filtering - Optimum linear filters for performing a spatial filtering operation on two dimensional signals with white additive noise, as used to enhance a representative digitized photograph taken by Lunar Orbiter III, were derived.[94]

Data Processing Planning - Support to each of the five teams of the NASA Computer Study continued. As background for the experiments team, a functional description of activities involved in handling pulse code modulation digital experiment data was prepared.[95] The activities were traced from raw data inception onboard the spacecraft to reduced results by the experimenters.

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(93) Some Space Shuttle Technology Considerations, Memorandum for File, D. E. Cassidy, December 29, 1969.

(94) Digital Filtering for Optimization of Signals Submerged in Noise, TM-69-1033-2, S. Y. Lee, October 7, 1969.

(95) Experiment Data Processing, Memorandum for File, R. J. Pauly, October 30, 1969.

ENGINEERING SUPPORT

Computing Facility

The UNIVAC 1108 computer operations were continued under the EXEC 8 multi-processing system. The major problem with EXEC 8 has been its instability; the intensive effort to identify and to fix the implementation errors has produced results. Further improvements in system stability can be made, but at the current time, instability is no longer a major problem in the usability of the EXEC 8 system.

During the period from October 1 to December 31, NASA Headquarters usage of the UNIVAC 1108 computer was 27,718 charge units.

ADMINISTRATIVE

Contract and Financial

During December, negotiations with NASA concerning statement of work, estimated cost and fixed fee, man years, and related subjects were held for the eighth contract period, January 1 through December 31, 1970. An amendment to the contract covering these matters has been executed, effective January 1, 1970.

LIST OF REPORTS AND MEMORANDA

(List in Order of Report Date)

This index includes technical reports and memoranda reported during this period covering particular technical studies.

The memoranda were intended for internal use. Thus, they do not necessarily represent the considered judgment of Bellcomm which is reflected in the published Bellcomm Technical Reports.

TITLE	DATE
Development Status of Lunar Mass Spectrometers, Memorandum for File, G. K. Chang	October 3, 1969
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